

POLYHYDROXYALKANOATE
COPOLYMER/STARCH COMPOSITIONS FOR LAMINATES AND FILMS

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[0001] The present application claims benefit of USSN 60/343,569 filed October 19, 2001.

FIELD OF THE INVENTION

[0002] The present invention relates to films comprising a polyhydroxyalkanoate copolymer (PHA)/destructured starch blend. Laminates having a first layer consisting essentially of a PHA copolymer and a second layer comprising either a PHA copolymer/destructured starch blend or thermoplastic starch are also disclosed. The films or laminates are used to make environmentally degradable disposable articles, particularly for degradation under anaerobic conditions.

BACKGROUND OF THE INVENTION

[0003] This invention relates to the need for alleviating the growing environmental problem of excessive plastic waste that makes up an increasing volume fraction of materials in landfills. Biodegradable polymers and products formed from biodegradable polymers are becoming increasingly important in view of the desire to reduce the volume of solid waste materials generated by consumers each year. The invention further relates to the need for developing new plastic materials that can be used in applications where biodegradability, compostability or biocompatibility are among primary desirable features of such applications, particularly under anaerobic conditions. There have been many attempts to make degradable articles. However, because of costs, the difficulty in processing, and end-use properties, there has been little commercial success. Many compositions that have excellent degradability have only limited processability. Conversely, compositions which are more easily processable have reduced degradability.

[0004] A conventional disposable absorbent product is already to a large extent compostable. A typical disposable diaper, for example, consists of about 80% of compostable materials, e.g., wood pulp fibers, and the like. Nevertheless, there is a particular need to replace polyethylene backsheet in absorbent articles with liquid impervious films of compostable material, because the backsheet is typically one of the largest non-compostable components of a conventional disposable absorbent article.

[0005] To produce films that have more acceptable end-use properties, choosing acceptable degradable polymers is challenging. The degradable polymers should be thermoplastic such that conventional film processing methods can be employed, including running on converting lines. Further, it

is important that the film or large film fragments undergo an initial breakup to much smaller particles during the initial stages of composting.

[0006] In addition, there has been an emerging interest in the breathability of disposable hygiene products to minimize the discomfort associated with the accumulation of high humidity. Breathable films that can contain liquid while allowing some passage of moisture vapor are of special interest in constructing such products. Controlling the pore size is achieved by dispersing filler particles uniformly and very finely within the film matrix before a stretching operation. Materials such as polyolefin have such a low affinity to filler surface that it is difficult to obtain a good dispersion of particles. Polyesters have a better affinity to many solid surfaces so that particles tend to spread more easily, however, if the interaction is too strong, the desired mechanical failure at the interface between the filler and film matrix to create pores during the stretching will not occur. Materials with a moderate level of interaction with fillers are needed for breathable films. Further, such materials must be substantially ductile to prevent macroscopic mechanical failure leading to large tears during the stretching. For example, typical aromatic polyesters such as polyethylene terephthalate are too brittle to contain the localized mechanical failure around the individual filler particles.

[0007] Polyhydroxyalkanoates (PHAs) are generally semicrystalline, thermoplastic polyester compounds such as isotactic poly(3-hydroxybutyrate) or PHB, and isotactic poly(3-hydroxybutyrate-co-valerate) or PHBV. Both copolymers suffer the drawbacks of high crystallinity and fragility/brittleness. Due to the slow crystallization rate, a film made from PHBV will stick to itself even after cooling; a substantial fraction of the PHBV remains amorphous and tacky for long periods of time. In both cast film operations and in blown films, residual tack limits processing. Medium to long side-chain PHAs, such as isotactic polyhydroxyoctanoates (PHOs), are virtually amorphous owing to the recurring pentyl and higher alkyl side-chains. When present, their crystalline fraction however has a very low melting point as well as an extremely slow crystallization rate. For example, Gagnon, *et al.* in *Macromolecules*, 25, 3723-3728 (1992), incorporated herein by reference, show that the melting temperature is around 61°C and that it takes about 3 weeks to reach the maximum extent of crystallization at its optimal crystallization temperature.

[0008] Further poly(3-hydroxyalkanoate) copolymer compositions have been disclosed by Kaneka (U.S. 5,292,860) and Procter & Gamble (U.S. 5,498,692; 5,536,564; RE 36,548; 5,685,756; 5,942,597; 5,990,271; 6,160,199). All describe various approaches of tailoring the crystallinity and melting point of PHAs to any desirable lower value than in the high-crystallinity PHB or PHBV by randomly incorporating controlled amounts of "defects" along the backbone that partially impede the crystallization process. The semicrystalline copolymer structures can be tailored to melt in the typical use range between 80°C and

150°C and are less susceptible to thermal degradation during processing. In addition, the biodegradation rate of these copolymers is higher as a result of their lower crystallinity and the greater susceptibility to microorganisms. Yet, whereas the mechanical properties and melt handling conditions of such copolymers are generally improved over that of PHB or PHBV, their rate of crystallization is characteristically slow, often slower than PHB and PHBV.

[0009] In general, it has been a considerable challenge to convert these newer PHA copolymers, as well as other biodegradable polymers, into useful forms by conventional melt methods. The polymers remain substantially tacky after they are cooled down from the melt and remain as such until sufficient crystallinity sets in, particularly with PHA copolymers with noncrystallizing component levels above 10 wt%. Residual tack typically can lead to material sticking to itself or to the processing equipment, or both, and thereby can restrict the speed at which a polymeric product is produced or prevent the product from being collected in a form of suitable quality.

[0010] To produce environmentally degradable articles, attempts have been made to process natural starch on standard equipment using existing technology known in the plastics industry. Since natural starch generally has a granular structure, it needs to be "destructured" before it can be melt processed. Modified starch (alone or as the major component of a blend) has been found to have poor melt extensibility, resulting in difficulty in successful production of fibers, films, foams or the like.

[0011] To produce films or laminates that have more acceptable processability and end-use properties, biodegradable polymers need to be combined with starch. Selection of a suitable biodegradable polymer that is acceptable for blending with starch is challenging. The biodegradable polymer must have a suitable melting temperature. The melting temperature must be high enough for end-use stability to prevent melting or structural deformation, but not too high of a melting temperature to be able to be processable with starch without burning the starch. These requirements make selection of a biodegradable polymer to produce starch-containing films very difficult. Further, the blend must be processable on conventional film making equipment.

[0012] U.S. 5,874,486 is to polymeric compositions comprising a matrix including a starch component and at least one of certain synthetic thermoplastics polymeric components in which a filler is dispersed and including a fluidising agent. U.S. 6,117,925 is to mixtures of transesterification products of starch and certain hydrophobic polymers. U.S. 6,096,809 is to compositions including thermoplastic starch and at least one of certain polymers wherein the water content of the composition is less than 1% while in a melted state. U.S. 5,844,023 is to a polymer dispersion consisting essentially of a mixture of thermoplastic starch and at least one of certain polymers and a phase mediator molecularly coupling the two phases.

Improvements can be made in the miscibility, processability, texture, feel, and tackiness of these prior art compositions.

[0013] For breathable film fabrication, there is a need to develop environmentally degradable materials that have a moderate affinity for solid filler surfaces for good particle dispersion and that are soft and ductile to have only localized mechanical failure to create fine pores upon stretching.

SUMMARY OF THE INVENTION

[0014] Environmentally degradable melt processed blended films comprising a polyhydroxyalkanoate copolymer (PHA) and destructured starch are disclosed. Laminates comprising a first layer consisting essentially of a PHA copolymer as described herein and a second layer comprising either a PHA copolymer/destructured starch blend or thermoplastic starch as described herein are also disclosed. Such blended compositions or laminates provide material properties different and improved in any one or more properties as compared to PHA copolymers alone or to starch films alone. Properties in which the blended materials or laminates are different and improved are any one of hardness/softness, brittleness/flexibility, tack, stickiness, toughness, ductility, processability, opaqueness/transparency, or breathability, for example. Further, breathable films comprising PHA/starch blends are disclosed. Disposable articles comprising the environmentally degradable films are also disclosed. Blends of the present invention are aerobically and anaerobically biodegradable, not very sensitive to moisture, and have good shelf life stability, while maintaining soft and flexible characteristics.

[0015] One of the most surprising aspects of blending PHAs with starch is that starch plasticizers are not required to make the blend melt processable. Starch can be destructured in water. The water-based destructured starch can then be compounded with PHA and the water vented off, while not adversely affecting the molecular weight profile of the PHA since it is hydrolytically stable.

DETAILED DESCRIPTION OF THE INVENTION

[0016] Copolymer compositions used herein are in mole percent. All other percentages, ratios and proportions used herein are by weight percent of the composition, unless otherwise specified.

[0017] The specification contains a detailed description of (1) materials of the present invention, (2) film or laminate properties, (3) method of film or laminate manufacture, and (4) disposable products.

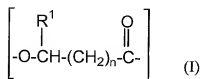
[0018] The present invention is directed toward films or laminates comprising polyhydroxyalkanoate copolymer and destructured starch. The polyhydroxyalkanoate copolymer renders the film or laminate rapidly environmentally degradable, particularly under anaerobic conditions. Starch is totally biodegradable. PHA/starch blends of the present invention are stable to moisture, and articles made

from such blends remain flexible. The present invention is also directed toward breathable films comprising a PHA copolymer/starch blend. The starch provides a nucleating agent for the stretching operation to create pores, thereby behaving as a particulate filler. However, a particulate filler may be added to a PHA copolymer/starch breathable film composition.

(1) Materials

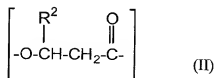
[0019] Polyhydroxyalkanoate Copolymers (PHAs)

[0020] The biodegradable films or laminates are formed in part from a composition comprising at least a first biodegradable polyhydroxyalkanoate copolymer comprising at least two randomly repeating monomer units (RRMUs). The first RRMU has the structure (I):

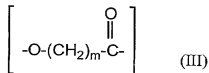


wherein R^1 is H, or C1 or C2 alkyl, and n is 1 or 2. In a preferred embodiment, R^1 is a methyl group (CH_3). In a further preferred embodiment of the first RRMU, R^1 is methyl and n is 1, whereby the polyhydroxyalkanoate copolymer comprises 3-hydroxybutyrate units.

[0021] The second RRMU included in the biodegradable polyhydroxyalkanoate copolymer comprises at least one monomer selected from the group consisting of the structures (II) and (III):



wherein R^2 is a C3-C19 alkyl or C3-C19 alkenyl, and

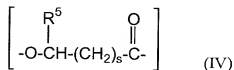


wherein m is from 2 to about 9. Generally, in the RRMU of formula (II), the length of R^2 will, to some extent, influence the reduction in overall crystallinity of the copolymer. In a preferred embodiment, R^2 is a C3-C15 alkyl group or alkenyl group. In a further preferred embodiment, R^2 is a C3-C9 alkyl group, and

in a further preferred embodiment, R^2 is a C5 or C7 alkyl group. In alternately preferred embodiments, R^2 is a C15-C19 alkyl or alkenyl group. In the RRMU of formula (III), the length of $(CH_2)_m$ will generally, to some extent, influence the reduction in overall crystallinity of the copolymer. In a preferred embodiment, m is from 2 to 9, and more preferably is from 2 to 5. In a further preferred embodiment, m is 5.

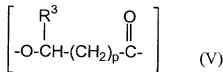
[0022] Preferably, to obtain the advantageous combination of physical properties exhibited by the films when using the polyhydroxyalkanoate composition, at least about 50 mole percent of the copolymer comprise RRMUs having the structure of the first RRMU of formula (I). Suitably, the molar ratio of the first RRMUs to the second RRMU in the copolymer is in the range of from about 50:50 to about 98:2. More preferably, the molar ratio is in the range of from about 75:20 to about 95:5, and even more preferred, the mole ratio is in the range of from about 80:20 to about 90:10. In addition, the polyhydroxyalkanoate copolymer suitably has a number average molecular weight of greater than about 150,000 g/mole, and further having a melting point designated T_m 1.

[0023] In further embodiments of the first polyhydroxyalkanoate copolymer employed in the compositions of the complex film, one or more additional RRMUs may be included. Suitably, the additional RRMUs may have the structure (IV):



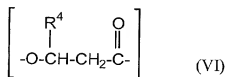
wherein R^5 is H, or a C1-C19 alkyl or alkenyl group and s is 1 or 2, with the provision that the additional RRMUs are not the same as the first or second RRMUs.

[0024] In further preferred embodiments, the polyhydroxyalkanoate composition further comprises a second biodegradable polyhydroxyalkanoate homo- or copolymer, or blend thereof. A preferred second PHA polymer or copolymer comprises at least one randomly repeating monomer unit having the structure (V):

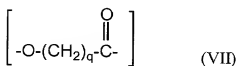


wherein R^3 is H, or C1 or C2 alkyl, and p is 1 or 2. In a preferred embodiment, R^3 is a methyl group (CH_3). In a further preferred embodiment, R^3 is methyl and p is 1, whereby the second polyhydroxyalkanoate polymer comprises 3-hydroxybutyrate units. In a further preferred embodiment, the

second polyhydroxyalkanoate polymer is the polyhydroxybutyrate homopolymer. Optionally, the second environmentally degradable polymer comprises two or more additional randomly repeating monomer units selected from the group consisting of the structures (VI) and (VII):



wherein R⁴ is a C2-C19 alkyl or C2-C19 alkenyl, and



wherein q is from 2 to about 16. With reference to the second RRMU comprising a monomer of structure (VII), in a preferred embodiment, q is from 2 to about 10, and more preferably is from about 4 to about 8. In a further preferred embodiment, q is about 5. When present, the additional randomly repeating monomer units represent no more than 25% of the total monomer units, preferably less than 15%, wherein the second polyhydroxyalkanoate homo- or copolymer suitably has a number average molecular weight of greater than about 50,000 g/mole. Further, the second biodegradable polyhydroxyalkanoate has a melting point Tm2 which is at least about 20°C greater than the melting point, Tm1, of the first biodegradable polyhydroxyalkanoate, so that the equation Tm2 > Tm1 + 20°C is satisfied. The value of the melting point is generally determined by DSC (Differential Scanning Calorimetry) and is taken as the highest endothermic peak temperature observed on the DSC heating scan using, for example, the method outlined in ASTM D 3418. Although not intending to be bound by theory, it is believed that the second biodegradable polyhydroxyalkanoate can act as a nucleating agent for the first biodegradable polyhydroxyalkanoate and thereby improve the crystallization rate of the first biodegradable polyhydroxyalkanoate if the adequate blend composition, structure and high level of dispersion is achieved.

[0025] If the second polyhydroxyalkanoate copolymer is used as described above, a majority of the PHA composition comprises the first biodegradable polyhydroxyalkanoate copolymer, whereby the second biodegradable PHA is finely dispersed throughout a continuous phase or matrix of the first copolymer and is included in an amount sufficient to improve the crystallization rate and/or physical properties of the first copolymer. In one embodiment, compositions comprise from about 0.01 to about 10 weight percent of the

second PHA copolymer, based on the total weight of the first and second PHA copolymers. In more specific embodiments, the compositions comprise from about 0.1 to about 5 weight percent of the second PHA. In even more specific embodiments, the compositions comprise from about 0.1 to about 3 weight percent of the second PHA copolymer.

[0026] The biodegradable polyhydroxyalkanoate copolymers can be synthesized by chemical or biological methods as disclosed, for example, in U.S. 5,618,855, 5,942,597, 5,990,271, RE 36,548, or 6,160,199, each of which is incorporated herein by reference.

[0027] The copolymer may be present as a continuous phase in the composition. The compositions may include a combination of polyhydroxyalkanoate copolymers, or a combination with other polymeric components, for example additional polyester components or the like.

[0028] PHA copolymers have excellent affinity to solid particle surfaces, such as starch, thereby allowing for straightforward dispersion of such particles during a stretching step in producing breathable films. PHA copolymers can be stretched without macroscopic tear.

[0029] Typically, polyhydroxyalkanoate copolymers are present in blends of the present invention in an amount of from greater than 25 % to 99%, preferably from 30% to 95%, more preferably from 40% to 90%, and most preferably from 50% to 80%, by weight of the film in the absence of a plasticizer.

[0030] Typically, polyhydroxyalkanoate copolymers are present in blends in an amount of from 15% to 99%, preferably from 30% to 90%, more preferably from 40% to 80%, and most preferably from 50% to 70%, by weight of the film in the presence of plasticizer.

[0031] Destructured Starch

[0032] The present invention relates to the use of starch, a low cost naturally occurring polymer. Since natural starch generally has a granular structure, it needs to be destructured before it can be melt processed. Commonly, starch is destructured by dissolving the starch in water. The term "thermoplastic starch" means starch destructured with a plasticizer.

[0033] Suitable naturally occurring starches can include, but are not limited to, corn starch, potato starch, sweet potato starch, wheat starch, sago palm starch, tapioca starch, rice starch, soybean starch, arrow root starch, bracken starch, lotus starch, cassava starch, waxy maize starch, high amylose corn starch, and commercial amylose powder. Blends of starch may also be used. Though all starches are useful herein, the present invention is most commonly practiced with natural starches derived from agricultural sources, which offer the advantages of being abundant in supply, easily replenishable and

inexpensive in price. Naturally occurring starches, particularly corn starch, wheat starch, and waxy maize starch, are the preferred starch polymers of choice due to their economy and availability.

[0034] Modified starch is destructured starch and may also be used. Modified starch is defined as non-substituted or substituted starch that has had its native molecular weight characteristics changed (i.e. the molecular weight is changed but no other changes are necessarily made to the starch). If modified starch is desired, chemical modifications of starch typically include acid or alkali hydrolysis, or oxidative chain scission to reduce molecular weight or molecular weight distribution. Natural, unmodified starch generally has a very high average molecular weight and a broad molecular weight distribution (e.g. natural corn starch has an average molecular weight of up to about 60,000,000 grams/mole (g/mol)). The average molecular weight of starch can be reduced to the desirable range for the present invention by acid reduction, oxidation reduction, enzymatic reduction, hydrolysis (acid or alkaline catalyzed), physical/mechanical degradation (e.g., via the thermomechanical energy input of the processing equipment), or combinations thereof. The thermomechanical method and the oxidation method offer an additional advantage when carried out *in situ*. The exact chemical nature of the starch and molecular weight reduction method is not critical as long as the average molecular weight is in an acceptable range. Ranges of molecular weight for starch or starch blends added to the melt is from about 3,000 g/mol to about 10,000,000 g/mol, preferably from about 10,000 g/mol to about 2,000,000 g/mol, and more preferably from about 20,000 g/mol to about 1,000,000 g/mol.

[0035] For gelatinization, the starch can be destructurized in the presence of a solvent which acts as a plasticizer. The solvent and starch mixture is heated, typically under pressurized conditions and shear to accelerate the gelatinization process. Chemical or enzymatic agents may also be used to destructure the starch by oxidation or derivatization, for example.

[0036] Although not required, substituted starch, also a destructured starch, can be used. If substituted starch is desired, chemical modifications of starch typically include etherification or esterification. Substituted starches may be desired for better compatibility or miscibility with the PHA copolymer. However, this must be balanced with the reduction in their rate of degradability. The degree of substitution of the chemically substituted starch is from about 0.01 to 3.0. A low degree of substitution, 0.01 to 0.06, may be preferred.

[0037] Typically, the destructured starch portion of a blended composition comprises from about 1% up to 75%, preferably from about 5% to 70%, more preferably from about 10% to about 60%, and most preferably from about 20% to about 50%, of starch in the absence of a plasticizer.

[0038] Typically, the destructured starch portion of a blended composition is in an amount of from 1 % to 85%, preferably from 10% to 80%, more preferably from 20% to 70%, and most preferably from 30% to 60%, by weight of the film in the presence of a plasticizer.

[0039] The weight of starch in the composition includes starch and its naturally occurring bound water content. The term "bound water" means the water found naturally occurring in starch and before mixing of starch with other components to make the composition of the present invention. The term "free water" means the water that is added in making the composition of the present invention. A person of ordinary skill in the art would recognize in light of the present disclosure that once the components are mixed in a composition, water can no longer be distinguished by its origin. The starch typically has a bound water content of about 5% to 16% by weight of starch. It is known that additional free water may be incorporated as the polar solvent or plasticizer, and not included in the weight of the starch.

[0040] Exemplary starches that may be used in the present invention are StarDri 100, StaDex 10, StaDex 15, or StaDex 65, all from Staley. StaDex 10 and StaDex 15 are white dextrin from dent corn starch. These dextrans have low solubility in cold water and are used as binders in adhesive applications where high viscosity is required. StaDex 65 is also a white dextrin from dent corn starch, has medium solubility in cold water and is used as a binder in adhesive applications where high viscosity at medium solids level is required. The StarDri materials are pre-structured multidextrin starches typically used in food applications.

[0041] Further Ingredients

[0042] Environmentally degradable thermoplastic polymers that are substantially compatible with PHA and with starch may be included in the films or laminates of the present invention. "Substantially compatible" means when heated to a temperature above the softening and/or the melting temperature of the composition, the polymer is capable of forming a substantially homogeneous mixture with the PHA and starch after mixing with shear or extension. Furthermore, the inclusion of the compatible polymer should not substantially reduce the performance of the starch and PHA blend. The thermoplastic polymer must be able to flow upon heating to form a processable melt and resolidify as a result of crystallization or vitrification.

[0043] The polymer must have a melting temperature sufficiently low to prevent significant degradation of the starch during processing and yet be sufficiently high for thermal stability during use of the film or laminate. Suitable melting temperatures of biodegradable polymers are from about 80° to about 230°C and preferably from about 90° to about 200°C. The polymer must have rheological characteristics suitable for film forming.

[0044] Nonlimiting examples of biodegradable thermoplastic polymers suitable for use in the present invention include aliphatic polyesteramides; diacids/diols aliphatic polyesters; modified aromatic polyesters including modified polyethylene terephthalates, modified polybutylene terephthalates; aliphatic/aromatic copolyesters; polycaprolactones; poly(3-hydroxyalkanoates) including poly(3-hydroxybutyrate), poly(3-hydroxyhexanoate, and poly(3-hydroxyvalerate); polyesters and polyurethanes derived from aliphatic polyols (i.e., dialkanoyl polymers); polyamides including polyethylene/vinyl alcohol copolymers; lactic acid polymers including lactic acid homopolymers and lactic acid copolymers; lactide polymers including lactide homopolymers and lactide copolymers; glycolide polymers including glycolide homopolymers and glycolide copolymers; and mixtures thereof.

[0045] Also suitable in the present invention are polyvinyl alcohol and its copolymers.

[0046] Preferred is a homopolymer or copolymer of polylactic acid having a melting temperature from about 160° to about 175°C. The environmentally degradable thermoplastic polymers must be able to solidify fairly rapidly, preferably under extensional flow, and form a thermally stable film structure, as typically encountered in known processes as cast or blown film extrusion methods.

[0047] Specific examples of preferred lactic acid polymers or lactide polymers suitable for use herein include, but are not limited to, those polylactic acid-based polymers or polylactide-based polymers that are generally referred to in the industry as "PLA". Therefore, the terms "polylactic acid", "polylactide" and "PLA" are used interchangeably to include homopolymers or copolymers of lactic acid or lactide based on polymer characterization of the polymers being formed from a specific monomer or the polymers being comprised of the smallest repeating monomer units. It should be understood, however, that the terms "polylactic acid", "polylactide", and "PLA" are not intended to be limiting with respect to the manner in which the polymer is formed. An example of commercially available polylactic acid polymers include a variety of polylactic acids that are available from the Chronopol Inc. (Golden, CO), or polylactides sold under the tradename EcoPLA®. Further examples of suitable commercially available polylactic acid include NATUREWORKS from Cargill Dow, LACEA from Mitsui Chemical, or a PLA resin L5000 from Biomer.

[0048] Depending upon the specific polymer used, the process, and the final use of the film or laminate, more than one polymer may be desired. It is preferred that two different polymers are used. For example, if a crystallizable polylactic acid having a melting temperature of from about 160° to about 175° C is used, a second polylactic acid having a lower melting point and lower crystallinity than the other polylactic acid and/or a higher copolymer level may be used. Alternatively, an aliphatic aromatic

polyester may be used with crystallizable polylactic acid. If two polymers are desired, the polymers need only differ by chemical stereo specificity or by molecular weight.

[0049] In one aspect of the present invention, it may be desirable to use a biodegradable thermoplastic polymer having a glass transition temperature of less than 0°C. Polymers having this low glass transition temperature include EASTAR BIO and BIONELLE.

[0050] A plasticizer can be used in the present invention to destructure the starch and enable the starch to flow, i.e. create a thermoplastic starch. The same plasticizer may be used to increase melt processability or two separate plasticizers may be used. The plasticizers may also improve the flexibility of the final products, which is believed to be due to the lowering of the glass transition temperature of the composition by the plasticizer. The plasticizers should preferably be substantially compatible with the polymeric components of the present invention so that the plasticizers may effectively modify the properties of the composition. As used herein, the term "substantially compatible" means when heated to a temperature above the softening and/or the melting temperature of the composition, the plasticizer is capable of forming a substantially homogeneous mixture with starch.

[0051] An additional plasticizer or diluent for the biodegradable thermoplastic polymer may be present to lower the polymer's melting temperature and improve overall compatibility with the thermoplastic starch blend. Furthermore, biodegradable thermoplastic polymers with higher melting temperatures may be used if plasticizers or diluents are present which suppress the melting temperature of the polymer. The plasticizer will typically have a molecular weight of less than about 100,000 g/mol and may preferably be a block or random copolymer or terpolymer where one or more of the chemical species is compatible with another plasticizer, starch, polymer, or combinations thereof.

[0052] Nonlimiting examples of useful hydroxyl plasticizers include sugars such as glucose, sucrose, fructose, raffinose, maltodextrose, galactose, xylose, maltose, lactose, mannose erythrose, glycerol, and pentaerythritol; sugar alcohols such as erythritol, xylitol, malitol, mannitol and sorbitol; polyols such as ethylene glycol, propylene glycol, dipropylene glycol, butylene glycol, hexane triol, and the like, and polymers thereof; and mixtures thereof. Also useful herein as hydroxyl plasticizers are poloxomers and poloxamines. Also suitable for use herein are hydrogen bond forming organic compounds which do not have hydroxyl group, including urea and urea derivatives; anhydrides of sugar alcohols such as sorbitan; animal proteins such as gelatin; vegetable proteins such as sunflower protein, soybean proteins, cotton seed proteins; and mixtures thereof. Other suitable plasticizers are phthalate esters, dimethyl and diethylsuccinate and related esters, glycerol triacetate, glycerol mono and diacetates, glycerol mono, di, and tripropionates, butanoates, stearates, lactic acid esters, citric acid esters, adipic acid esters, stearic acid

esters, oleic acid esters, and other fatty acid esters which are biodegradable. Aliphatic acids such as ethylene acrylic acid, ethylene maleic acid, butadiene acrylic acid, butadiene maleic acid, propylene acrylic acid, propylene maleic acid, and other hydrocarbon based acids. All of the plasticizers may be used alone or in mixtures thereof. A low molecular weight plasticizer is preferred. Suitable molecular weights are less than about 20,000 g/mol, preferably less than about 5,000 g/mol and more preferably less than about 1,000 g/mol. Further suitable plasticizers are those described in U.S. Patent Nos. 3,182,036 and 5,231,148.

[0053] Preferred plasticizers include glycerine, mannitol, and sorbitol. The amount of plasticizer is dependent upon the molecular weight and amount of starch and the affinity of the plasticizer for the starch. Generally, the amount of plasticizer increases with increasing molecular weight of starch. Typically, the plasticizer present in the final film composition comprises from about 2% to about 70%, more preferably from about 5% to about 55%, most preferably from about 10% to about 50%.

[0054] Optionally, other ingredients may be incorporated into the composition in quantities of less than about 50%, preferably from about 0.1% to about 20%, and more preferably from about 0.1% to about 12% by weight of the composition. The optional materials may be used to modify the processability and/or to modify physical properties such as elasticity, tensile strength and modulus of the final product. Other benefits include, but are not limited to, stability including oxidative stability, brightness, color, flexibility, resiliency, workability, processing aids, viscosity modifiers, and odor control.

[0055] Nonlimiting examples of other optional ingredients include aromatic/aliphatic polyester copolymers made more readily hydrolytically cleavable, and hence more likely biodegradable, such as those described in U.S. 5,053,482, 5,097,004, 5,097,005, and 5,295,985, biodegradable aliphatic polyesteramide polymers, polycaprolactones, polyesters or polyurethanes derived from aliphatic polyols (i.e., dialkanoyl polymers), polyamides including polyethylene/vinyl alcohol copolymers, cellulose esters or plasticized derivatives thereof, salts, slip agents, crystallization accelerators such as nucleating agents, crystallization retarders, odor masking agents, cross-linking agents, emulsifiers, surfactants, cyclodextrins, lubricants, other processing aids, optical brighteners, antioxidants, flame retardants, dyes, pigments, fillers, proteins and their alkali salts, waxes, tackifying resins, extenders, antiblocking agents, antistatic agents, or mixtures thereof. Slip agents may be used to help reduce the tackiness or coefficient of friction in the film. Also, slip agents may be used to improve film stability, particularly in high humidity or temperatures. A suitable slip agent is polyethylene. A salt may also be added to the melt to make the film more water responsive or used as a processing aid. A salt will also function to help reduce the solubility of a binder so it does not dissolve, but when put in water or flushed, the salt will dissolve then enabling the binder to dissolve and create a more aqueous-responsive product.

[0056] Fabrication of breathable films includes extensively stretching a PHA copolymer/starch film. The starch provides a nucleating agent for the stretching operation to create pores, thereby behaving as a particulate filler. However, a particulate filler or coarse grain pigment may be added to a PHA copolymer/starch breathable film composition. Such fillers include numerous types of inorganic or organic solids, such as talc, calcium carbonate, mica, kaolin, plastic beads, latex, or the like. Inorganic fillers further include fillers such as the oxides of magnesium, aluminum, silicon, or titanium; hydrous magnesium silicate, titanium dioxide, clay, dirt, chalk, boron nitride, limestone, diatomaceous earth, glass, quartz, or ceramics. If present, particulate fillers are typically present in an amount of from about 1% to about 50% based on the particular ingredient and use of the breathable film.

[0057] Further examples of other ingredients are known to one of skill in the art in light of the present disclosure.

[0058] Although starch is the preferred natural polymer in the present invention, a protein-based polymer could also be used. Suitable protein-based polymers include soy protein, zein protein, or combinations thereof. The protein-based polymer may be present in an amount of from about 0.1% to about 80% and preferably from about 1% to about 60%.

(2) Film or Laminate Properties

[0059] The present invention is in the form of a film or laminate, as described in U.S. 5,498,692, and uses blended or laminated compositions as described herein. As used herein, "blend" means a composition having two or more ingredients (i.e., PHA with destructured starch). As used herein, "film" means an extremely thin continuous piece of a substance having a high length to thickness ratio and a high width to thickness ratio. While there is no requirement for a precise upper limit of thickness, a preferred upper limit would be 0.254 mm, more preferably still about 0.01 mm, more preferably still about 0.005 mm. The protective value of any film depends on its being continuous, i.e., without holes or cracks. Breathable films have been stretched to produce continuous pores that prevent penetration of liquid and that pass moisture vapor. A breathable film may be one layer of a multilayer film. The film may be a multilayer film, i.e., a laminate or composite. A laminate is defined as two or more films joined together. A laminate may have one or more layers comprising a blended PHA copolymer/starch composition as set forth herein. In another embodiment, a laminate may have a first layer comprising a PHA copolymer as described herein and a second layer comprising a PHA copolymer/starch film or a thermoplastic starch as set forth herein. The laminate may have a first layer comprising a PHA copolymer, a second layer comprising a PHA/starch blend or a thermoplastic starch, and a third layer comprising PHA, or any combination of layers desired. As used, the terms first, second, or third layers are simply used to describe separate layers and are not intended to be limiting as to the location of the layer. A preferred embodiment of the invention is a

laminate having three layers wherein the outer two layers comprise a PHA copolymer and the intermediate layer comprises a PHA copolymer/starch blend or thermoplastic starch.

[0060] The film of the present invention can be employed in a variety of disposable products including, but not limited to, disposable diapers, shrink-wrapping (e.g., food wraps, consumer product wraps, pallet and/or crate wraps, and the like), or bags (grocery bags, food storage bags, sandwich bags, resealable "Ziploc®"-type bags, garbage bags, and the like). In one embodiment of the present invention, the film is a liquid impervious backsheet or a perforated topsheet and is suitable for use in absorbent disposable sanitary garments such as disposable diapers, feminine hygiene products or the like. Films of the present invention, in addition to increased biodegradability and/or compostability, may have properties as set forth in U.S. 5,990,271.

[0061] The films or laminates produced in the present invention are environmentally degradable. "Environmentally degradable" is defined as being biodegradable, disintegratable, "aqueous-responsive," dispersible, flushable, or compostable or a combination thereof. In the present invention, the films, multilayer films (laminates) and articles are environmentally degradable. As a result, the films or laminates can be easily and safely disposed of either in existing composting facilities or may be flushable and can be safely flushed down the drain without detrimental consequences to existing sewage infrastructure systems. The environmental degradability of the films or laminates of the present inventions offer a solution to the problem of accumulation of such materials in the environment following their use in disposable articles. The flushability of the films of the present invention when used in disposable products, such as wipes and feminine hygiene items, offer additional convenience and discreteness to the consumer. Although biodegradability, disintegratability, "aqueous-responsiveness," dispersibility, compostability, and flushability all have different criteria and are measured through different tests, generally the films or laminates of the present invention will meet more than one of these criteria.

[0062] Biodegradable is defined as meaning when the matter is exposed to an aerobic and/or anaerobic environment, the ultimate fate is reduction to monomeric components due to microbial, hydrolytic, and/or chemical actions. Under aerobic conditions, biodegradation leads to the transformation of the material to end products such as carbon dioxide and water. Under anaerobic conditions, biodegradation leads to the transformation of the materials to carbon dioxide, water, and methane. The biodegradability process is often described as mineralization. Biodegradability means that all organic constituents of the films are subject to decomposition eventually through biological activity.

[0063] A variety of different standardized biodegradability methods have been established by various organizations and in different countries. Although the tests vary in the specific testing conditions,

assessment methods, and criteria desired, there is reasonable convergence between different protocols so that they are likely to lead to similar conclusions for most materials. For aerobic biodegradability, the American Society for Testing and Materials (ASTM) has established ASTM D 5338-92: Test Methods for Determining Aerobic Biodegradation of Plastic Materials Under Controlled Composting Conditions. The test measures the percent of test material that mineralizes as a function of time by monitoring the amount of carbon dioxide being released as a result of assimilation by microorganisms in the presence of active compost held at a thermophilic temperature of 58°C. Carbon dioxide production testing may be conducted via electrolytic respirometry. Other standard protocols, such as 301B from the Organization for Economic Cooperation and Development (OECD), may also be used. Standard biodegradation tests in the absence of oxygen are described in various protocols such as ASTM D 5511-94. These tests are used to simulate the biodegradability of materials in an anaerobic solid-waste treatment facility or sanitary landfill.

[0064] The films or laminates of the present invention may rapidly biodegrade. Quantitatively, this is defined in terms of percent of material converted to carbon dioxide after a given amount of time. Disintegration may also occur. Disintegration is when the film or laminate has the ability to rapidly fragment and break down into fractions small enough not to be distinguishable after screening when composted or to cause drainpipe clogging when flushed. A disintegratable material may also be flushable. Most protocols for disintegratability measure the weight loss of test materials over time when exposed to various matrices. Both aerobic and anaerobic disintegration tests are used. Weight loss is determined by the amount of test material that is no longer collected on an 18 mesh sieve with 1 millimeter openings after the materials is exposed to wastewater and sludge. For disintegration, the difference in the weight of the initial sample and the dried weight of the sample recovered on a screen will determine the rate and extent of disintegration. The testing for biodegradability and disintegration are similar since essentially the same environment is used for testing. To determine disintegration, the weight of the material remaining is measured, while for biodegradability, the evolved gases are measured.

[0065] The films or laminates of the present invention will also be compostable. ASTM has developed test methods and specifications for compostability. The test measures three characteristics: biodegradability, disintegration, and lack of ecotoxicity. Tests to measure biodegradability and disintegration are described above. To meet the biodegradability criteria for compostability, the material must achieve at least about 60% conversion to carbon dioxide within 40 days. For the disintegration criteria, the material must have less than 10% of the test material remain on a 2 millimeter screen in the actual shape and thickness that it would have in the disposed product. To determine the last criteria, lack of ecotoxicity, the biodegradation byproducts must not exhibit a negative impact on seed germination and plant growth. One test for this criteria is detailed in OECD 208. The International Biodegradable Products Institute will issue a logo for compostability once a product is verified to meet ASTM 6400-99

specifications. The protocol follows Germany's DIN 54900 which determine the maximum thickness of any material that allows complete decomposition within one composting cycle.

[0066] The films of the present invention may be thermally bondable. Thermally bondable films are required for the pressurized heat and thru-air heat bonding methods. The films may also be laminated or heat sealed. A lower melting polymer may be desired for heat sealing. Multiple material may be preferred to achieve optimal conditions for heat sealing. Films comprising PHA blended with starch or laminates comprising a PHA copolymer/starch blended layer can improve the bonding characteristics of the films.

(3) Method of Film or Laminate Manufacture

[0067] The films or laminates of the present invention having increased environmental degradability and/or compostability may be processed using conventional procedures for producing single or multilayer films on conventional film-making equipment. Destructured starch is mixed with a ductile semicrystalline polyhydroxyalkanoate copolymer to produce a thermo-processable composition. Pellets of the PHA/starch blends of the present invention can be made by first dry blending and then melt mixing in a film extruder. Alternatively, if insufficient mixing occurs in the film extruder, the pellets can be first dry blended and then melt mixed in a precompounding extruder followed by repelletization prior to film extrusion.

[0068] Co-processing with starch requires a relatively low process temperature to minimize the thermal decomposition of starch. PHA melts at a temperature lower than 150 °C, so thermal decomposition of starch is minimized.

[0069] The PHA/starch blends of the present invention can be melt processed into films using either cast or blown film extrusion methods both of which are described in *Plastics Extrusion Technology-2nd Ed.*, by Allan A. Griff (Van Nostrand Reinhold-1976). Cast film is extruded through a linear slot die. Generally the flat web is cooled on a large moving polished metal roll. It quickly cools, and peels off this first roll, passes over one or more auxiliary cooling rolls, then through a set of rubber-coated pull or "haul-off" rolls, and finally to a winder.

[0070] In blown film extrusion, the melt is extruded upward through a thin annular die opening. This process is also referred to as tubular film extrusion. Air is introduced through the center of the die to inflate the tube and thereby causing it to expand. A moving bubble is thus formed which is held at a constant size by control of internal air pressure. The tube of film is cooled by air, blown through one or more chill rings surrounding the tube. The tube is then collapsed by drawing it into a flattening frame through a pair of pull rolls and into a winder. For backsheet applications the flattened tubular film is subsequently slit open, unfolded, and further slit into widths appropriate for use in products.

[0071] Both cast film and blown film processes can be used to produce either monolayer or multilayer film structures. For the production of monolayer films from a single thermoplastic material or blend of thermoplastic components only a single extruder and single manifold die are required.

[0072] For the production of multilayer films or laminates of the present invention, coextrusion processes are preferably employed. Such processes require more than one extruder and either a coextrusion feedblock or multi-manifold die system or combination of the two to achieve the multilayer film structure.

[0073] U.S. Pat. Nos. 4,152,387, and 4,197,069, disclose the feedblock principle of coextrusion. Multiple extruders are connected to the feedblock which employs moveable flow dividers to proportionally change the geometry of each individual flow channel in direct relation to the volume of polymer passing through said flow channels. The flow channels are designed such that at their point of confluence, the materials flow together at the same flow rate and pressure eliminating interfacial stress and flow instabilities. Once the materials are joined in the feedblock, they flow into a single manifold die as a composite structure. It is important in such processes that the melt viscosities and melt temperatures of the materials do not differ too greatly; otherwise flow instabilities can result in the die leading to poor control of layer thickness distribution in the multilayer film.

[0074] An alternative to feedblock coextrusion is a multi-manifold or vane die as disclosed in aforementioned U.S. Pat. Nos. 4,152,387, 4,197,069, and in U.S. Pat. No. 4,533,308. Whereas in the feedblock system melt streams are brought together outside and prior to entering the die body, in a multi-manifold or vane die each melt stream has its own manifold in the die where the polymers spread independently in their respective manifolds. The melt streams are married near the die exit with each melt stream at full die width. Moveable vanes provide adjustability of the exit of each flow channel in direct proportion to the volume of material flowing through it, allowing the melts to flow together at the same linear flow rate, pressure, and desired width.

[0075] Since the melt flow properties and melt temperatures of the processed materials may vary widely, use of a vane die has several advantages. The die lends itself toward thermal isolation characteristics wherein materials of greatly differing melt temperatures, for example up to 175° F. (80° C.), can be processed together.

[0076] Each manifold in a vane die can be designed and tailored to a specific polymer (or copolymer). Thus the flow of each polymer is influenced only by the design of its manifold, and not by

forces imposed by other polymers. This allows materials with greatly differing melt viscosities to be coextruded into multilayer films. In addition, the vane die also provides the ability to tailor the width of individual manifolds, such that an internal layer, for example a water soluble biodegradable polymer like Vinex 2034, can be completely surrounded by water insoluble materials leaving no exposed edges susceptible to water. The aforementioned patents also disclose the combined use of feedblock systems and vane dies to achieve more complex multilayer structures.

[0077] The multilayer films of the present invention may comprise two or more layers. In general, balanced or symmetrical three-layer and five-layer films are preferred. Balanced three-layer multilayer films comprise a center core layer and two identical outer layers, wherein said center core layer is positioned between said two outer layers. Balanced five-layer multilayer films comprise a center core layer, two identical tie layers, and two identical outer layers, wherein said center core layer is positioned between said two tie layers, and a tie layer is positioned between said center core layer and each outer layer. Balanced films, though not essential to the films of the present invention, are less prone to curling or warping than unbalanced multilayer films.

[0078] In three layer films, the center core layer may comprise 10 to 80 percent of the films' total thickness and each outer layer comprises 10 up to 50 percent of the films' total thickness. Tie layers, when employed, each comprise from about 5 percent to about 10 percent of the films' total thickness.

[0079] Breathable films are fabricated by extensively stretching a film. The stretching may be performed uniformly across the film, for example, as achieved in a tenter framing process such as described by J. H. Briston in Plastics Films, 2nd Edition, Longman Inc., New York (1983), pages 83-85. Alternatively, the film can be stretched incrementally across the film, for example, as in ring-rolling operations such as those described in U.S. Patents 4,116,892 and 5,296,184 where alternating parallel regions that are stretched coexist with regions that remain virtually unstretched. Stretching the film causes localized mechanical failure of adhesion between the starch and the polymer matrix. Such failure creates void structures around the starch, leading to the formation of fine continuous pores across the film. The pore diameter is sufficiently small so as to prevent the penetration of liquid due to a disproportionately large capillary force associated with a very small radius of curvature. Thus, liquid is safely contained by the porous film. The fine continuous pore is capable of passing moisture vapor since the transport of vapor is not hindered by the capillary force. To achieve control of fine pore formation, the starch is dispersed uniformly and very finely within the film matrix before the stretching operation. The PHA or PHA/starch blends of the present invention can be stretched without macroscopic tear.

(4) Disposable Products

[0080] The present invention further relates to disposable products comprising a PHA/starch blend or a laminate of the present invention. For example, compostable absorbent articles comprising a liquid pervious topsheet, a liquid impervious backsheet comprising a film of the present invention (e.g., a film comprising a PHA/starch blend of the present invention), and an absorbent core positioned between the topsheet and backsheet. Such absorbent articles include infant diapers, adult incontinent briefs and pads, and feminine hygiene pads and liners. Disposable personal care products include breathable products that contain liquid while allowing some passage of moisture vapor.

[0081] Additional products comprising a PHA/starch blend or laminate of the present invention include personal cleansing wipes; disposable health care products such as bandages, wound dressings, wound cleansing pads, surgical gowns, surgical covers, surgical pads; other institutional and health care disposables such as gowns, wipes, pads, bedding items such as sheets and pillowcases, and foam mattress pads.

[0082] Films or laminates of the present invention used as liquid impervious backsheets in absorbent articles of the present invention, such as disposable diapers, typically have a thickness of from 0.01 mm to about 0.2 mm, preferably from 0.012 mm to about 0.051 mm.

[0083] Other examples of absorbent articles according to the present invention are sanitary napkins designed to receive and contain vaginal discharges such as menses. Disposable sanitary napkins are designed to be held adjacent to the human body through the agency of a garment, such as an undergarment or a panty or by a specially designed belt. Examples of the kinds of sanitary napkins to which the present invention is readily adapted are shown in U.S. 4,687,478, Aug. 18, 1987, and in U.S. 4,589,876, May 20, 1986. It will be apparent that the films of the present invention comprising a PHA/starch blend or laminate of the present invention described herein may be used as the liquid impervious backsheet of such sanitary napkins. On the other hand it will be understood the present invention is not limited to any specific sanitary napkin configuration or structure.

[0084] Importantly, the absorbent articles according to the present invention are biodegradable and/or compostable to a greater extent than conventional absorbent articles which employ materials such as a polyolefin (e.g., a polyethylene backsheet).

EXAMPLE 1

[0085] This example is to demonstrate the processing of binary blends comprising a preferred polyhydroxyalkanoate copolymer and unplasticized destructured starch. Specifically, blends containing a

polyhydroxyalkanoate copolymer of 3-hydroxybutyrate with about 12 mole percent 3-hydroxyhexanoate (hereafter a PHBH copolymer) and destructured starch are melt processed into films using a cast film extrusion method. StarDri 1 and PHBH are blended together at 150°C and mixed thoroughly. There was not starch plasticizer present. The level of PHBH is varied from 10 to 90 weight percent based on the total weight of PHBH and equivalent dry weight of starch. It was found that PHBH levels need to be above 25 weight percent in order to form a useful film.

EXAMPLE 2

[0086] This example is to demonstrate the processing of binary blends comprising a preferred polyhydroxyalkanoate copolymer and plasticized destructured (thermoplastic) starch. Specifically, blends containing a polyhydroxyalkanoate copolymer of 3-hydroxybutyrate with about 12 mole percent 3-hydroxyhexanoate (hereafter a PHBH copolymer) and thermoplastic starch are melt processed into films using a cast film extrusion method. A 70/30 blend of StarDri 1/sorbitol and PHBH are blended together at 150°C and mixed thoroughly. The level of PHBH is varied from 10 to 100 weight percent based on the total weight of PHBH and equivalent dry weight of starch. It was found that PHBH levels need to be above 15 weight percent in order to form a useful film that was not exceedingly tacky. Films could be made in all ratios in the present example.

EXAMPLE 3-32

[0087] This example demonstrates the processing of a bilayer laminate film. A PHBH polymer described in EXAMPLE 1 is used in a first layer. A PHBH/thermoplastic starch blend described in EXAMPLE 2 is used in a second layer. The laminate is constructed according to the table below by a coextrusion process:

Example #	1st Layer (%)	2nd Layer (%)	2nd Layer Composition (% PHBH)	Composition (%Starch)
3	10	90	0	100
4	10	90	10	90
5	10	90	25	75
6	10	90	50	50
7	10	90	75	25
8	10	90	90	10
9	25	75	0	100
10	25	75	10	90
11	25	75	25	75
12	25	75	50	50
13	25	75	75	25
14	25	75	90	10
15	50	50	0	100
16	50	50	10	90
17	50	50	25	75
18	50	50	50	50
19	50	50	75	25

20	50	50	90	10
21	75	25	0	100
22	75	25	10	90
23	75	25	25	75
24	75	25	50	50
25	75	25	75	25
26	75	25	90	10
27	90	10	0	100
28	90	10	10	90
29	90	10	25	75
30	90	10	50	50
31	90	10	75	25
32	90	10	90	10

EXAMPLE 33

[0088] This example demonstrates the processing of a trilayer laminate film using the PHBH copolymer from Example 1 in the outer (first and third) layers or alternatively the middle (second) layer. When the PHBH copolymer is the outer layers, a PHA/thermoplastic starch blend in EXAMPLE 2 is used in the middle (second) layer, and in this embodiment the starch may comprise up to about 90% of the blend. When the PHA/thermoplastic starch blend is the outer (first and third) layers, the middle layer may be a PHBH copolymer. In this embodiment, the starch portion of the blend is up to 50%. Coextrusion processes are used to produce the trilayer laminate film according to:

Example #	1st Layer (%)	2nd Layer (%)	2nd Layer (% PHBH)	Composition (% Starch)	3rd Layer (%)
34	10	80	0	100	10
35	10	80	10	90	10
36	10	80	25	75	10
37	10	80	50	50	10
38	10	80	75	25	10
39	10	80	90	10	10
40	25	50	0	100	25
41	25	50	10	90	25
42	25	50	25	75	25
43	25	50	50	50	25
44	25	50	75	25	25
45	25	50	90	10	25
46	50	50	0	100	10
47	50	40	10	90	10
48	50	40	25	75	10
49	50	40	50	50	10
50	50	40	75	25	10
51	50	40	90	10	10
52	50	25	0	100	25
53	50	25	10	90	25
54	50	25	25	75	25
55	50	25	50	50	25
56	50	25	75	25	25
57	50	25	90	10	25

58	45	10	0	100	45
59	45	10	10	90	45
60	45	10	25	75	45
61	45	10	50	50	45
62	45	10	75	25	45
63	45	10	90	10	45

EXAMPLE 64

[0089] A 100 gram per square meter, 27.5 volume percent calcium carbonated loaded PHBH resin/starch cast film is biaxially oriented and evaluated for water vapor transmission rate. Each sample is stretched 400% in the machine direction and held for 5 seconds. The samples are then stretched 0%, 50%, 100%, 150%, 250%, and 400% in the cross-machine direction. Each sample is held for 5 seconds in the stretched position. The samples will then be tested for water vapor transmission rate. It is expected that films stretched in the machine direction only have relatively low water vapor transition rates. As the amount of stretch in the cross-machine direction is increased, the water vapor transition rate will be increased to values many fold (i.e. 4 to 30 times) greater than the unstretched film.

[0090] The disclosures of all patents, patent applications (and any patents which issue thereon, as well as any corresponding published foreign patent applications), and publications mentioned throughout this description are hereby incorporated by reference herein. It is expressly not admitted, however, that any of the documents incorporated by reference herein teach or disclose the present invention.

[0091] While particular embodiments of the present invention have been illustrated and described, it would be obvious to those skilled in the art in light of the present disclosure that various other changes and modifications can be made without departing from the spirit and scope of the invention. It is intended to cover in the appended claims all such changes and modifications that are within the scope of the invention.